Report on the
RSVP Detector Capabilities, Simulation, and Backgrounds Review

January 11-13, 2005
New York University

Executive Summary

The KOPIO and MECO experiments address important fundamental questions and are of great interest to the particle physics community. Both experiments involve risk, since they must achieve excellent background rejection in the face of extremely difficult experimental environments. After hearing detailed presentations on the simulations that underlie the sensitivity and background estimates of both experiments, the review committee is satisfied that both experiments have reasonable prospects of meeting their goals. However, we cannot at this time provide assurance that either will do so. We do find that steps can be taken to clarify and subsequently reduce the risks, and we urge the RSVP project and the KOPIO and MECO collaborations to give high priority to taking these steps as soon as possible. These steps include developing software to carry out more realistic simulations and making measurements of critical beam and detector parameters. The high priority measurements will require a significant level of effort not only from the collaborations, but also the staff of the BNL Alternating Gradient Synchrotron (AGS). Some will require operating the AGS at high intensity. (These measurements require high intensity per pulse, not large integrated intensity.)

KOPIO seeks to measure the $K_L \to \pi^0 \nu \bar{\nu}$ branching fraction. The experimental signature of this mode is difficult to say the least, since only two photons from the π^0 decay are observable. The technique employed by KOPIO requires an extraordinary level performance from its photon veto system (10^{-8} rejection for π^0s from other sources), which must operate in a very intense neutral beam environment. To make the necessary time-of-flight measurement of K_L momentum, narrow microbunching of the beam with good extinction between microbunches is needed. While KOPIO has done a good job addressing many issues via simulation, a clear inadequacy of the simulations is the lack of detector digitization and realistic event reconstruction. An increased level of manpower devoted to software and simulations is clearly needed. We recommend that, as soon as possible, KOPIO:

- Develop a detector Monte Carlo with full digitization of detector signals, and realistic event reconstruction starting from "raw data" in order to validate background estimates.
- Develop a fully engineered design for the barrel photon veto, build a full-scale prototype, and subject it to beam tests to validate that it achieves the required performance.
- Perform tests with the AGS to measure beam microbunch width and inter-bunch extinction at full intensity (at least 70 Tp/spill) and to demonstrate the necessary bunch widths and extinction are achieved.

- Design the neutral beam and shielding, install it, and perform beam tests (using specialized detectors) to establish that the properties of the beam (e.g., n halo) meet the requirements of the experiment.

KOPIO projects 12,000 hours of data-taking to be needed for a branching fraction measurement of ±12% if $K_L \rightarrow \pi^0 \nu\bar{\nu}$ occurs at 3×10^{-11}. Based on current information, the committee finds this to be a reasonable estimate. However, we emphasize that (1) a short early run with only a partial detector can make an interesting physics measurement because it would have sensitivity to non-Standard Model physics, and (2) once a $K_L \rightarrow \pi^0 \nu\bar{\nu}$ signal is established, the precision of the branching fraction is expected to improve only with the square root of running. Thus, KOPIO's success depends upon achieving the required beam and detector performance and meeting it goals for background rejection, rather than meeting a particular target for total running time.

MECO seeks to perform a stringent test of separate lepton number conservation by looking for the conversion of a muon to electron in the field of a nucleus at the level of 2×10^{-17} (w.r.t. $\mu N \rightarrow \nu_\mu N'$). Reaching this goal requires achieving an extraordinary level of extinction between beam bunches (10^{-9}). The experiment utilizes a large and complex series of superconducting magnets and detector elements (including a straw tracker) that must operate in vacuum. While MECO has done a good job addressing many issues via simulation, a clear inadequacy of the simulations is the lack of detector digitization and realistic event reconstruction. An increased level of manpower devoted to software and simulations is clearly needed. We recommend that, as soon as possible, MECO:

- Develop a detector Monte Carlo with full digitization of detector signals, and realistic event reconstruction starting from "raw data" to validate background estimates.
- Perform tests with the AGS to demonstrate the required extinction when running at 8 GeV with intensity of at least 20 Tp/spill.
- Continue to develop more realistic simulations of the full target/transport channel/detector chain to further explore exotic background scenarios.

In addition, the committee recommends that <u>both</u> KOPIO and MECO:

- Develop deliverables-based schedules with performance milestones, which include the steps recommended in this report planned for completion as early as possible.

By doing so, dangerous surprises may be avoided later. If serious problems are found early, there will be a much better chance that solutions can be found and implemented in time to avoid major degradation of the experiment.

Finally, the scenario described to us for AGS running during RHIC data-taking, while perhaps conservative, would provide only a marginal amount of RSVP running per year. We urge BNL to make it a high priority to maximize AGS slow spill running during RHIC operation. Also, both KOPIO and MECO should benefit if data-taking is structured to provide the longest possible runs in alternate years, rather than shorter runs based on an equal division of available running each year.

Introduction

The RSVP Project Office organized this review to address the reliability of estimates of the sensitivity and background rejection of the KOPIO and MECO experiments. The membership of the review committee is listed in Appendix 1. The charge to the committee is included as Appendix 2. The agenda for the three-day meeting conducted at New York University can be found in Appendix 3.

The committee reached consensus on its conclusions and recommendations during the review and presented them in a closeout report at the end of the review. The Executive Summary essentially presents the contents of the closeout report. In the body of this report, we provide additional discussion for each experiment of a number of topics that are important in assessing their status and prospects.

Discussion of KOPIO Issues

<u>Running Time and Beam Fluxes</u>

KOPIO proposes to run for 12,000 hours at the AGS with extracted proton intensity of 100 Tp/spill (1 Tp = 1×10^{12} protons). The highest demonstrated AGS intensity is 70 Tp/spill. KOPIO's ultimate sensitivity could be less than expected if fluxes prove to be less than estimated. This could occur either as a failure to reach 100 Tp/spill from the AGS, or from K_L flux per proton in the neutral beam being less than estimated. To the extent that KOPIO can optimize spill parameters with any given proton intensity, the sensitivity of the experiment degrades more slowly than linear with decreased intensity. A run with an optimized spill at 70 Tp/spill provides sensitivity only about 15% worse than running at 100 Tp/spill for the same duration. This is fortunate since significant effort will be needed to achieve 100 Tp/spill.

KOPIO's estimate of K_L flux produced at 42° in 25.5 GeV proton interactions with a thick Pt target is based on measurements of the E-802 charged-particle fluxes produced by 14.6 GeV/c protons. The yield at 42° is scaled to the desired proton energy using small-angle charged-particle production data at 23.1 GeV/c. Similarly, the K_L flux from Pt is estimated using the A-dependence of the measured yields from Be, Al, Cu, and Au targets. While these procedures are reasonable, there are uncertainties associated with them. The KOPIO collaboration quotes a 20% uncertainty in the resulting K_L flux.

Thus, shortfalls in both proton intensity and K_L flux per proton are possible. This illustrates the importance of the fact that KOPIO's success does not hinge upon making a branching fraction measurement with high precision. Rather, it rests upon convincingly establishing a signal for $K_L\rightarrow\pi^0\nu\bar{\nu}$ and making a moderately precise branching fraction measurement, which in principle should be possible with significantly less than 12,000 hours of data taken with less than 100 Tp/spill.

Microbunched Beam and Extinction

KOPIO requires beam microbunches of width less than 200 psec spaced by 40 nsec with extinction between microbunches of one part in 10^3. This should be achievable. We are encouraged by a 2002 AGS experimental observation of 240 psec wide bunches using a single 93 MHz cavity. We are also encouraged by a 2004 experiment, at 4.5 MHz, that observed an extinction of one part in 10^5, far better than needed. But we are concerned that (1) neither result was obtained at high intensity, and (2) the extinction result was observed at a much lower frequency.

During normal acceleration, protons are rapidly lost if they are not in an rf bucket. But during a flat top, protons can persist outside of an rf bucket. KOPIO requires higher frequency bunching than is used in normal AGS acceleration. So it is planned, after acceleration (at 4.5 MHz), to de-bunch after acceleration, and re-bunch at the higher frequency (25 MHz). Since the energy is constant during this procedure, protons could, in principle, survive between rf buckets. The extinction could be spoiled by problems either in the re-bunching, or by any mechanism that moves protons out of a bucket into the continuum. Noise in the rf during bunching might do the former. Energy loss from scraping on an extraction septum or collimator could do the latter, as could a longitudinal instability. Either mechanism could be worse at higher intensities. Such problems seem more likely at the higher bunching frequency, since the protons need to migrate a shorter distance into the inter-bunch region. Such problems might be worse with a very long flat top (5 sec), as planned by KOPIO, that leaves more time for the bunching to spoil.

We have no specific reason to believe that such mechanisms will be present, and thus no reason to believe that the required extinction will not be obtained. But the tests made to date do not guarantee that problems will not be encountered when the KOPIO rf systems are used at high intensity and slow extraction. Better simulation is promised, and is clearly desirable, but instabilities are hard to predict. We thus believe it is important to build the proposed system, and test it at high intensity, as soon as possible.

Therefore, we recommend that KOPIO, as soon as possible:

- Perform tests with the AGS to measure beam microbunch width and inter-bunch extinction at full intensity (at least 70 Tp/spill) and to demonstrate the necessary bunch widths and extinction are achieved.

Software and Simulations

KOPIO employs a mixture of simulation tools to address various beam and detector issues, including GEANT3, GEANT4, FLUKA, and others. The tools employed represent state-of-the-art and appropriate choices. Signal and background issues are addressed primarily with a “parameterized” Monte Carlo called FASTMC. While this is a standard approach at an early stage of an experiment, KOPIO has reached the point where more realism is needed if subtle issues of background rejection, such as the effects of noise hits upon reconstruction efficiencies, are to be reliably addressed.

FASTMC provides a first pass effort to account for signal inefficiencies resulting from the construction of higher-level event parameters such as tracks and clusters in a high rate environment. Nevertheless, we are concerned that unaccounted for losses associated with forming clean Pre-radiator tracks and linked calorimeter clusters will be significant. KOPIO is beginning to account for reconstruction and rate-related losses, which in aggregate now correspond to a loss of 57%. Additional losses being considered, such as Pre-radiator cluster splitting, are coming in each at several percent, further eroding the signal efficiency. These trends have been seen in previous rare decay experiments such as the KTeV experiment where unaccounted-for reconstruction losses and rate effects corresponded to a factor of two loss of final signal efficiency for $K_L \rightarrow \pi^0 ee$ with respect to initial projections at a stage similar to the state of KOPIO today. Similar losses in KOPIO, compared to current estimates, seem quite plausible to us. Therefore, it is of the utmost importance to develop more realistic simulations which provide full digitization of detector signals, so for instance the interference between hits can be correctly modeled, and to develop realistic reconstruction algorithms that operate on the realistic "raw data." We recommend that KOPIO, as soon as possible:

- Develop a detector Monte Carlo with full digitization of detector signals, and realistic event reconstruction starting from "raw data" in order to validate background estimates.

Manpower currently devoted to simulations was reported to be 4.5 FTEs. The committee did not probe this estimate, but notes that it includes a number of 0.5 FTE contributions, so that the number of persons focusing on these issues is quite small. A significantly higher level of effort will be required to implement our recommendation, and to develop an appropriate analysis framework to provide collaboration-wide access to MC and data analysis tools.

<u>Background Rejection</u>

Background rejection is the critical issue in the KOPIO experiment. KOPIO has invested significant effort in developing a strategy based on both kinematic information and photon vetos to deal with all identified backgrounds using their fast Monte Carlo. The most important background sources are $K_L \rightarrow \pi^0 \pi^0$ and $K_L \rightarrow \pi e \nu \gamma$. The signal-to-background level is estimated to be 0.42 for events with both photons measured in the Pre-radiator, giving an angle measurement, and about 0.28 for events with only one photon striking the Pre-radiator (assuming $K_L \rightarrow \pi^0 \nu \bar{\nu}$ occurs at 3×10^{-11}).

The Photon Veto system presents a particular vulnerability, owing to the exceptional performance requirements in terms of photon inefficiency and low energy threshold in the presence of high rates associated with a very intense neutral beam. Current estimates of photon inefficiency are based on E949 below 200 MeV and on FLUKA for energies above 200 MeV. However, the E949 beam and geometry are significantly different than that of KOPIO. We are concerned that KOPIO's much larger system, operating in a significantly different beam environment, poses many difficult challenges.

Great care should be taken to closely couple the simulations and the engineering design. We are especially concerned about mechanical supports and mechanical joins or gaps in the barrel and forward detector subsystems such as: the "projective" seams between cylindrical barrel Shashlyk modules, seams at the supports between forward Pre-radiator modules, and supports at the mechanical interface to outer Photon Veto modules added in the cylindrical barrel design. All regions should be studied as a function of photon energy in GEANT3/4 simulations with a realistic geometry description of the mechanical components and with statistics sufficient to characterize their effect on veto inefficiency and signal reconstruction.

While simulations will be an important input to the design process, confidence can only come from an experimental demonstration that a fully engineered (i.e., buildable) system will achieve the photon inefficiency. Therefore, the committee recommends that KOPIO, as soon as possible:

- Develop a fully engineered design for the barrel photon veto, build a full-scale prototype, and subject it to beam tests to validate that it achieves the required performance.

<u>Detector and veto rate considerations.</u>

KOPIO requires a high level of background rejection from veto systems that must operate in a very challenging rate environment, which results from kaon decays and from soft particles associated with the intense neutral beam. Reducing detector rates to acceptable levels hinges on designing the beam and associated shielding to minimize beam halo and soft particle fluxes so that they are not the dominant sources of detector rates (as compared to kaon decays).

Realistic simulations are an important part of the design process for the beam and shielding. There are a number of areas where KOPIO could benefit from more detailed simulations. For example:

1. The contour of the carbon fiber composite beam pipe could be optimized. (The pipe will both intercept outer halo neutrons and degrade their spectrum since carbon is a good moderator.)
2. Neutrons in the detector volume can be moderated by hydrogenic and light materials. (There will also be neutron capture, with the attendant capture gammas. In some detectors these low energy gammas can cause singles rate and correlated rate problems via single and double Compton scattering. Their implications for detector performance should be evaluated.)
3. All moderate and low energy fluxes should be checked for potential detector impact, particularly on veto inefficiency/deadtime. These fluxes are not reliably modeled by GEANT3 with GHEISHA or FLUKA. (For GEANT4 neutron transport options, GEANT4 experts should be consulted.)

The next line of defense against high rates is excellent timing from the veto systems. KOPIO has made well-motivated and elegant detector technology choices to provide the required timing performance. However, of particular concern is the performance of the Beam Catcher, which must function in a 10+ GHz beam of neutrons. The design of the Beam Catcher has been validated in low intensity beam tests, but there have yet to be high intensity tests that can challenge the requirement of 3 nsec double-pulse resolution. A demonstration of this timing performance, short of an actual beam test, would be an important next step in reducing the technical risk associated with the veto systems. Also of concern is the role that the Pre-radiator must play as a veto system. The Pre-radiator system is the only KOPIO veto system with projective readout, which exacerbates rate effects. In contrast the Barrel Veto, Calorimeter, and Beam Catcher are "pixelized" with a tower geometry, which significantly reduces the maximum rate/channel. The KOPIO collaboration should work expeditiously to develop a strategy to explicitly use Pre-Radiator data to form veto objects so that the associated signal losses can be understood, and possibly mitigated with design changes at this early stage.

While detailed simulations are critical for successful beam and shielding design, due to the high risk associated with the neutral beam, and the experience of many previous rare kaon decay experiments which found that beam backgrounds were their limiting factor, it would be wise to design and build the neutral beam as soon as possible, and test its actual performance. Therefore, the committee recommends that KOPIO, as soon as possible:

- Design the neutral beam and shielding, install it, and perform beam tests (using specialized detectors) to establish that the properties of the beam (e.g., n halo) meet the requirements of the experiment.

We note that having the actual beam would also make it possible at an early stage to remove the uncertainties (discussed earlier) in the K_L flux. It would also provide perhaps the only appropriate test beam in the world for the Beam Catcher.

Discussion of MECO Issues

Running Time and Beam Fluxes

MECO proposes to run for 10^7 sec (about 2800 hours) with 40 Tp/spill from the AGS, after the running required to commission the experiment has been completed. This would provide a single event sensitivity of 2×10^{-17}. This depends on achieving an extremely high μ^-/p ratio, several orders of magnitude higher than any previous experiment. This is a feature of the capture of pions by the graded solenoid that MECO employs. Muon flux estimates depend not only on the capture, but also on the cross section for low-energy pion production by 8 GeV protons, which is not well-known, and estimates of the stopping probability and capture probability.

The estimation of the pion flux produced by 8 GeV protons on a long gold target is estimated from measured pion yields from 10 GeV protons on Ta. The experimental invariant cross sections are scaled to 8 GeV using several hadronic models. GEANT3 FLUKA and GEANT4 QGSP appear to be the best suited for this purpose. However, the predicted low-energy pion multiplicities from these codes do not agree well with thin-target measurements. MECO uses a conservative estimate of low-energy pion (and consequently muon) fluxes in their subsequent estimation of beam rates.

While there are uncertainties in the MECO flux estimates, they do not seem unduly optimistic. Perhaps the most optimistic assumption is 40 Tp/spill from the AGS. Fortunately, some shortfall can be made up by additional running time.

Beam Extinction

MECO requires that the protons be captured in just two rf buckets (the AGS rf provides 6 buckets, all of which are normally filled), spaced by 1.35 microseconds. In each bucket there would be 2×10^{13} protons (about double that in each bunch in normal AGS running, but giving fewer total protons per fill). MECO requires exceptional extinction between these two bunches: no more than one part in 10^9. In order to achieve this, it is proposed to destabilize unfilled buckets during acceleration and extraction, and in addition provide an active kicker system in the extraction line to remove protons between the bunches.

We are encouraged by the experimental observation of extinction as good as one part in 10^7 when operating near the MECO energy. This was at low intensity, but used the same rf as would be used in MECO. We note also that once the required extinction is achieved, migration into the intra-bunch region requires relatively long drift and might be expected to be slow compared with the loss from the destabilization. The use of the second level of extinction in the external beam line appears sound.

Nevertheless, unexpected instabilities could cause problems, and might not be apparent until the system is operated at the required intensity. Since the success of MECO depends on achieving the target level of extinction, we recommend that MECO, as soon as possible:

- Perform tests with the AGS to demonstrate the required extinction when running at 8 GeV with intensity of at least 20 Tp/spill.

We note that the MECO goal is running with 40 Tp/spill, and of course tests at that intensity are desirable. However, our understanding is that due to both technical and administrative reasons, it may be possible to perform the required tests much earlier if the intensity does not exceed 22 Tp/spill. Our emphasis is on performing early tests at an intensity at which MECO could operate viably, even if it is below the optimal intensity.

Software and Simulations

MECO employs a mixture of simulation tools to address various beam and detector issues. There are multiple issues, which overlap with background rejection and other issues discussed later in this report. These include: simulation of the particle fluxes and transport through the magnetic channel, simulation of the detector performance, and an analysis framework for the experiment.

MECO has made good use of GEANT3 to simulate particle fluxes from the production target and graded field solenoid, as well as transport through the S-shaped collimator and $\bar{p}$-absorber. If simulation now turns to the question of particle trapping/latency in the upstream section, care will be required to check the numerical accuracy for trajectories making many turns in the trapping region (as it has been checked already for particles that transport through the system normally).

Problems involving neutron transport require other tools. Work in other experiments has shown that that neutron transport from high energy down to thermal can be simulated consistently (typically to within factors of 1.05 to 2.00 depending on energy, material type, and material depth) using GEANT/Gcalor or Standalone FLUKA. (These fluxes are not reliably modeled by GEANT3 with GHEISHA or FLUKA. For GEANT4 neutron transport options, GEANT4 experts should be consulted.)

There are a number of areas where MECO could benefit from more detailed analysis using these codes. For example, neutrons produced in the stopping target will be moderated by any hydrogenic and light materials in the detector. In turn, there will be neutron capture, with associated capture gammas. In some detector designs these low energy capture gammas can cause singles rate and correlated rate problems via single and double Compton scattering. In MECO, the rate of such effects in the three-layer scintillator shield should be calculated from simulation.

Also if, until now, collimator performance has been evaluated using only GEANT3 with GHIESHA or (internal) FLUKA, it should be re-simulated with neutron transport codes. There may be unexpected problems associated with low energy neutrons or photons produced in the collimators. In general, all fluxes transported by the above codes should be checked for unwanted effects, such as the creation of false signals or increases in the veto deadtime.

Simulation of the detector performance plays a critical role in background estimates. Presentations at the review described the status of simulations of the straw tracker, the calorimeter, and the cosmic ray veto. Our concerns focus on the straw tracker, which provides the ultimate background rejection through the precision measurement of electron momentum. The issue is whether the high rate environment introduces problems that have not been fully simulated. An effort has been made to include such effects, but without a full MC simulation which digitizes detector signals and correctly deals with cases such as two hits close in time on the same wire, coupled with a realistic pattern reconstruction algorithm, we are not confident that possible pathological topologies have not been overlooked, or that inefficiencies (after all cuts) may not prove to be larger than expected. Therefore, the committee recommends that MECO, as soon as possible:

- Develop a detector Monte Carlo with full digitization of detector signals, and realistic event reconstruction starting from “raw data” in order to validate background estimates.

Closely related to implementing this recommendation is the matter of establishing a framework that integrates Monte Carlo, reconstruction, and data analysis code and makes it accessible to the full collaboration. MECO’s plan for such a framework, described to the committee, is a good one. However, a significant infusion of manpower will be needed to implement it. We were told that current software/simulation manpower is 4-5 FTEs, while about 7.5 FTEs are needed. The estimate for what is needed is reasonable.

Background Rejection

The signature of a signal in MECO is the appearance of a 105.1 MeV electron coming from the stopping target. The most serious potential background comes from radiative pion capture. This background will be rendered insignificant by the pulsed beam structure with 10^{-9} inter-bunch extinction. Failure to achieve this extinction would seriously limit the experiment. Thus, we have already emphasized the importance of demonstrating this level of extinction as soon as possible.

The other important backgrounds come from the muons themselves and from cosmic rays. Here one can be guided both from the experience of the previous SINDRUM-II experiment and from simulation. The intrinsic background from muon decay in orbit is suppressed by good momentum resolution for the electron in the vacuum straw tracker. The advertised resolution, which is dominated by multiple scattering in the straws, is adequate. The concern that needs to be addressed through more realistic simulations is the possible mis-measurement of electron momentum that could result from pattern reconstruction errors that become possible in the presence of very high rates. I.e., noise hits can corrupt the “real” hits. Also, it is at least possible that realistic pattern recognition algorithms do not provide the expected efficiency in the presence of high rates. MECO has addressed these issues within their existing simulation framework, but more realistic simulations are needed. This has been addressed by our earlier recommendation for developing full detector digitization in the Monte Carlo and pattern recognition algorithms that operate on the MC-generated raw data.

An efficient cosmic-ray veto shield will reduce the cosmic ray background to a negligible level. This can be verified in the experiment, since cosmic-ray background events should extend well beyond 105 MeV. The presentation at this review on the cosmic ray veto system and the associated simulations left the committee with confidence that this is unlikely to be a problem for MECO.

In summary, the required background rejection depends on achieving the target extinction and the projected detector performance, especially for the tracking system. The needed extinction should be demonstrated as soon as possible. More realistic simulations can address the tracking issues.

Detector Performance

The MECO detector technologies are well suited to the low-mass, speed, and resolution requirements of this very challenging experiment. MECO is not inventing new technology to meet these requirements, but rather is pushing existing tracking and calorimetry techniques into new regimes. Operating straws and lead-tungstate crystals in vacuum present significant engineering challenges. The collaboration has addressed many of these, but several remain. Notable among the challenges is the effective cooling of the crystal calorimeter and readout in vacuum without the introduction of substantial dead material, and the operation of the straw readout in vacuum subject to a high radiation field. Before production begins on these key detector systems, fully engineered prototypes should be operated in vacuum to understand cooling of calorimeter systems, and possible damage mechanisms of the straw readout. Of particular concern for the straw readout are etching of the straw conductive surfaces by fast gases in a radiation field, and degradation of the straw mechanical properties in the high radiation field.

MECO has initiated a detailed simulation of the detector systems and has presented plausible arguments that the spectrometer systems have sufficient pattern recognition capability and resolution to suppress known backgrounds to the design level. Much work remains to be done to assess and account for reconstruction losses associated with rate effects and detector deadtime, particularly in the straw tracking system. This is addressed by our recommendation concerning full MC digitization of detector signals and realistic reconstruction algorithms. The review committee notes that the performance of the muon veto shield system may be over-specified, since the estimated background contribution from cosmic ray muons is far less than other sources. Relaxing the performance of the muon veto system may reduce deadtime (caused by beam related processes) from this veto system and possibly lower costs to the project.

Magnetic Field Tolerances and Pathological Trajectories

Magnetic field in the transport solenoid was designed to eliminate unwanted long-latency (i.e., trapped or nearly trapped) particles by requiring a graded field in each straight section. The field specification is conservative and has been confirmed by detailed calculations to be robust. The committee, however, is still concerned that there is some risk of a defect in the field, such as a local minimum. Trapped particles in such field, by being delayed or by scattering into the acceptance of the detector, could introduce background since no suppression factor from extinction would apply. In addition to such trapping, distorted trajectories of particles would modify the beam profile and hence degrade the effect of the collimators, which may affect efficiencies and detector rates as well as background rejection. Therefore, continuing studies should focus on anomalous trajectories using realistic simulations which assume field defects to understand their possible effects. Also, serious consideration should be given to monitoring the field to identify any anomalous features if they develop, from whatever cause.

While we are impressed with work already done by MECO understand these issues, and we have no specific reasons to question the results, we recommend that MECO:

- Continue to develop more realistic simulations of the full target/transport channel/detector chain to further explore exotic background scenarios.

Discussion of Issues Common to KOPIO and MECO

This review focused on the simulations, with emphasis on estimates of sensitivity and backgrounds. Beam and detector issues are inextricably related to those estimates, so they were also considered. The committee did not receive any information on schedules. Nonetheless, to reinforce our emphasis on giving high priority and immediate attention to some issues that have potentially far-reaching consequences, the committee makes one recommendation with respect to the schedules. The committee recommends that both KOPIO and MECO:

- Develop deliverables-based schedules with performance milestones, which include the steps recommended in this report planned for completion as early as possible.

By doing so, dangerous surprises may be avoided later. If serious problems are found early, there will be a much better chance that solutions can be found and implemented in time to avoid major degradation of the experiment.

There were no presentations at this review on scenarios for AGS slow spill running for RSVP. Informally, the committee was told by a BNL representative that, while perhaps conservative, projections are that 15 weeks of 80 hours/week of slow spill AGS running per year are possible with RHIC (assuming RHIC runs 29 weeks/year). An additional 10 weeks of 120 hours/week without RHIC are also possible. This suggests only 1200 to 2400 hours per year of RSVP running, which must be shared by KOPIO and MECO.

Short running periods of 2400 hours or less will not only cause RSVP running to require many calendar years, but will also introduce considerable inefficiency due to the edge effects associated with startups. The integrated cost of RSVP running will undoubtedly increase in such a scenario. While it is outside the scope of this review, it seems clear that BNL needs to give high priority to maximizing the slow spill running available during RHIC operation. The success of RSVP may depend on this.

Additionally, it is important to have a sensible distribution of available running time between KOPIO and MECO. The specific needs will depend on the status of the experiments and cannot be predicted today. However, a good guideline for planning is that long runs, separated by a period of sufficient duration to analyze the data, will be much more efficient and useful than short runs of both experiments every year. That is, alternating full-year KOPIO and MECO runs is likely to be much better than running both experiments each year.

Finally, we wish to emphasize the essential role the AGS, and therefore the AGS staff, must play in RSVP. Both KOPIO and MECO require the AGS to achieve challenging performance parameters that have never been achieved in the AGS, and indeed never achieved in any machine. A close working relationship between the collaborations and the AGS will be essential.

Appendix 1

Membership of the Committee

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Appendix 2

Charge to the Committee

RSVP Detector Capabilities, Simulations and Backgrounds Review

CHARGE

[1] For each of the KOPIO and MECO experiments, determine if the proposed detectors are capable of achieving the stated sensitivities and background suppression. Specific questions to address include:

(a) What is the current status of the detailed detector design?
(b) Is this design capable of achieving the desired resolutions, efficiencies, and hermeticity?
(c) What is the current status of the simulation studies?
(d) Do they indicate that acceptable signal and background levels can be achieved?
(e) How is the field specified in detail in the MECO magnet system, and what method is used to determine these specifications? What is the consequence for the rates and backgrounds if the desired field accuracy in various aspects is not achieved?
(f) What is the current status of beam studies? In particular, can desired extinction levels be achieved?
(g) Given the detector status in (a) thru (f) above, how much running will be required to achieve the stated sensitivities?

[2] If any of the issues in [1] above are judged to be currently inadequate, what does the review committee recommend doing to achieve the stated sensitivities and background rejection? What additional resources will be required to accomplish this? What time will be required to accomplish this?

[3] Are there any organizational, personnel, or resource issues which may hinder achievement of the stated sensitivities? If so, how does the review committee recommend they be addressed?

Appendix 3

Agenda

Tuesday, 11 January: KOPIO Experiment	**Time**
Morning Session	
Executive Session (30’)	08:30-09:00
KOPIO Overview (Bryman – 30’)	09:00-10:00
AGS & Beams (Sivertz – 30’)	10:00-10:30
BREAK (15’)	10:30-10:45
Detector (Littenberg – 45’)	10:45-11:30
Signal & Backgrounds (Jaffe – 60’)	11:30-12:30
LUNCH (90’)	12:30-14:00
Afternoon Session	
Conclusions (Littenberg – 15’)	14:00-14:15
Executive Session/Discussion (120’)	14:15-16:15
Questions to KOPIO, as needed (60’)	16:15-17:15
ADJOURN	17:15
Wednesday, 12 January: MECO Experiment	**Time**
Morning Session	
Executive Session (30’)	08:30-09:00
MECO Overview/Sources of background (Molzon – 45’)	09:00-09:45
Proton Beam & Extinction Requirements (Molzon – 15’)	09:45-10:00
Production Solenoid Environment (Tumakov – 30’)	10:00-10:30
BREAK (15’)	10:30-10:45
Muon Beam Simulations (Tumakov – 30’)	10:45-11:15
Magnetic Field Specifications & Tolerances (20’)	11:15-11:35
Tracker Requirements & Simulations (Hebert – 40’)	11:35-12:15
LUNCH (90’)	12:15-13:45
Afternoon Session	
Calorimeter Requirements & Simulations (Djilkibaev – 20’)	13:45-14:05
Cosmic Ray Veto Requirements & Simulations (Kane – 15’)	14:05-14:20
Plans for WBS 1.3.9 Simulations & Analysis(Kolomensky–10’)	14:20-14:30
BREAK (20’)	14:30-14:50
Executive Session/Discussion (120’)	14:50-16:50
Questions to MECO, as needed (70’)	16:50-18:00
ADJOURN	18:00
Thursday, 13 January	
Executive Session (30’)	08:30-09:00
Answers to Questions from KOPIO (60’)	09:00-10:00
Answers to Questions from MECO (60’)	10:00-11:00
BREAK (15’)	11:00-11:15
Executive Session (105’)	11:15-13:00
Closeout (60’)	13:00-14:00
ADJOURN	14:00